# EXPANDABLE BIT

## Field

This invention is directed to a drill bit for use in drilling a borehole through an earthen formation and, in particular, a drill bit that is expandable from a tripping position to a position for use.

## Background

A drill bit is used when drilling a borehole through an earthen formation. In some applications, such as casing drilling or extending a borehole below a cased section, the drill bit must be sized to fit through the casing drift diameter, but capable of drilling a borehole to a gauge larger than the outer diameter of the casing. To achieve this, an under reamer is often used with a pilot bit.

The under reamer is spaced back from the pilot bit and is generally pivotally attached such that it can be stored for tripping and expanded radially outwardly for use.

## Summary

A bit has been invented that is expandable from a collapsed position, useful for tripping, to an radially expanded position for use. The bit is useful to form a borehole through an earthen formation. In one embodiment, the bit can be used alone, without a separate under reamer, to expand a well bore below a casing string, either during casing drilling or when extending a well bore below an installed casing string.

In accordance with one broad aspect of the present invention there is provided a drill bit for forming a borehole through an earthen formation, the drill bit comprising: an upper end formed to be connectable to a drilling drive means, a lower end opposite the upper end; a center axis extending between the upper end and the lower end; a center cutter face on the lower end, the center cutter face selected to be useful to drill through an earthen formation; and an arm positioned between the center cutter

face and the upper end, the arm selected to be radially moveable relative to the center axis between a stored position defining a stored bit diameter and an expanded position defining an expanded bit diameter, greater than the stored bit diameter; and an outer cutter face disposed on the arm and exposable for use to drill through an earthen formation when the arm is in the expanded position.

The drilling drive means to which the upper end is connectable can vary depending on the type of drilling in which the bit is to be used. For example, the drilling drive means can be: a drill string formed of, for example, drill pipe or casing; a sub connectable to a drill string; a downhole motor, such as for example, a mud motor, for driving the bit; or a sub connected to a downhole motor.

The bit can include one or more arms, with consideration as to size and complexity of the bit. In the stored position, the bit is generally selected to be a size suitable for passing though the drift diameter of a tube string, such as a casing string and in the expanded position, the bit is generally selected to be capable of use to drill a bore hole of a gauge greater than the outer diameter of the tube string.

The outer cutter face and the center cutter face include cutters selected to be useful in forming a borehole through an earthen formation. In one embodiment, the center cutter face and the outer cutter face form a substantially continuous bit surface when the arm is in its expanded position.

The arm can be moveable between the expanded position and the stored position in any desired way, as by use of a slidable wedge arrangement or by use of a pivotal connection.

The bit can include jetting ports through which fluid can be passed, for example, for cleaning and lubricating the bit.

The bit can include a housing including an upper end, a lower end, an axis defined as extending through the upper end and the lower end and a bore extending parallel to the axis into the lower end; and the center cutter face is disposed on a mandrel slidingly disposed in the bore, the mandrel having a lower end and an upper end; and the arm being drivable into the expanded position by the mandrel bearing thereagainst to drive the arm out. The mandrel can be formed to support the arm,

when it is in the expanded position. For example, the arm can be formed to bear against the mandrel when it is in the expanded position. The mandrel and the arm can be formed such that they substantially conform to one another along a portion of their contacting surfaces once the arm is in its expanded position so that forces affecting the arm can be reacted through the mandrel. In its stored position, the arm can be positioned below the bore, adjacent the bore or can extend into the bore. Generally, it is desirable to form the arms such that they extend into the bore, when in the stored position, to reduce the stored size of the bit as much as possible.

Thus, in accordance with another broad aspect of the present invention there is provided a drill bit for forming a borehole through an earthen formation, the drill bit comprising: a housing including an upper end, a lower end, an axis defined as extending through the upper end and the lower end and a bore extending parallel to the axis into the lower end; a mandrel slidingly disposed in the bore, the mandrel having a lower end and an upper end; a centre cutter face on the mandrel lower end; an arm having a lower end and connected to the housing adjacent the bore, the arm being radially moveable about between a stored position and an expanded position, the arm being drivable into the expanded position by the mandrel bearing thereagainst to drive the arm out; and a outer cutter face on the arm lower end.

In one embodiment, the arm is positioned in a slot in the housing. The slot can be formed to conform about the arm side and upper surfaces to support the arm and provide for transfer of stress into the housing.

In one embodiment, the outer cutter face, when the arms are expanded, are substantially co-planar with the center cutter face. Thus in accordance with another broad aspect of the present invention, there is provided a drill bit for forming a borehole through an earthen formation, the drill bit comprising: a center cutter face; an arm positioned about the center cutter face and selected to be radially moveable relative to the center cutter face between a stored position defining a stored bit diameter and an expanded position defining an expanded bit diameter, greater than the stored bit diameter; and an outer cutter face disposed on the arm and selected such that when the arm is in the expanded position, the outer cutter face and the center cutter face are substantially co-planar.

Brief Description of the Drawings

A further, detailed, description of the invention, briefly described above, will follow by reference to the following drawings of specific embodiments of the invention. These drawings depict only typical embodiments of the invention and are therefore not to be considered limiting of its scope. In the drawings:

Figure 1 is an axial sectional view through a bit in accordance with the present invention, in an expanded position for use. Reference can be made to Figure 3 line 1-1 for understanding of the section which is illustrated in Figure 1;

Figure 1A is an axial sectional view of the bit of Figure 1 in a stored position;

Figure 2 is a transverse sectional view through the bit of Figure 1 taken along line 2-2;

Figure 3 is a transverse sectional view through the bit of Figure 1 taken along line 3-3;

Figure 4 is an end elevation of the bit of Figure 1;

Figure 5 is an end elevation of the bit of Figure 1A;

Figure 6 is a side view of an arm and slot of Figure 1;

Figure 6A is a side elevation of an arm useful in the bit of Figure 1;

Figure 6B is an axial sectional of the lower portion a bit housing useful in the bit of Figure 1;

Figure 7 is an axial sectional view through another bit in accordance with the present invention, in an expanded position for use. Reference is made to the sectional line 7-7 in Figure 10;

Figure 7A is an axial sectional view of the bit of Figure 7 in a collapsed, stored position;

Figure 8 is a transverse sectional view through the bit of Figure 7 taken along line 8-8;

Figure 9 is a side view of an arm and slot of Figure 7;

Figure 10 is an end elevation of the bit of Figure 7;

Figure 11 is an end elevation of the bit of Figure 7A;

Figure 12 is a side elevation of the lower portion of the bit of Figure 7;

Figure 13 is an axial sectional view through another bit in accordance with the present invention, in an expanded position for use. Reference is made to Figure 14, wherein the section of Figure 13 is shown along line 13-13;

Figure 13A is an axial sectional view of the bit of Figure 7 in a collapsed, stored position; and

Figure 14 is an end elevation of the bit of Figure 13.

Detailed Description

Referring to Figures 1 to 6, there is shown one embodiment of a bit according to the present invention. As will be appreciated, the bit is useful to form or extend a borehole. The bit is engageable at the lower end of a drill string. If the bit is used when drilling with casing, the drill string is a string of casing and the bit is releasably locked to the string of casing by, for example, a drilling lock assembly. The bit is rotated either by rotation of the casing string from surface or by use of a mud motor.

The bit includes a cutter face 10 formed of a center cutter face and an outer cutter face, a mandrel 12 and a housing 14.

Mandrel 12 includes a lower end 12a and an upper end 12b. In the illustrated embodiment, upper end 12b is formed as a blank. However, this blank will be milled or otherwise treated to a form suitable for connection to the drilling drive means. In one embodiment, the blank will be formed as a threaded pin end for connection to the drilling lock assembly or another component for eventual connection to the drill string. Mandrel further includes an inner bore 13.

Housing 14 includes an upper end 14a and a lower end 14b. Housing 14 further includes an upper inner bore 14c defined between a return 14d at the upper end of

the housing and a shoulder 14e. Housing 14 further includes a lower inner bore 14f extending below shoulder 14e.

The housing carries three, or any desired number of, bit arms 15. The bit arms are moveable between a stored position (Figure 1A), wherein they are retracted against or, as shown, into the housing and its inner bore and an expanded position (Figure 1) wherein they are supported for use to extend the well bore. The bit arms are moveable between the stored position and the expanded position by relative axial movement of the mandrel and the housing. In particular, when housing 14 is in a lower position relative to the mandrel wherein the mandrel is retracted into the bore of the housing bit arms 15 are in or can be driven into the stored position and when housing 14 is moved upwardly over mandrel 12, the bit arms are driven out to the expanded position. In the expanded position, lower end 12a of the mandrel is flush with or extends from lower end 14b of the housing. Bit arms 15 each retain cutters 16a, 16b over a portion of their outer surfaces. Bit arms 15, when in the expanded position, form the outer cutter face of the bit, as will be discussed in greater detail herein below.

Lower end 12a of the mandrel forms the center cutting face and retains cutters 18 on its lower outer surface forming the center cutter face, as will be described in greater detail hereinbelow.

Mandrel 12 is positioned in the inner bore of housing 14 and housing 14 is slidably mounted to move axially over mandrel 12. Mandrel 12 includes an annular groove defined by shoulder 19a and annular flange 19b which limit movement of the housing over the mandrel by abutment against upper end 14a and return 14d of the housing. When the bit is not in operation, housing 14 is normally in a lower position relative to the mandrel wherein return abuts against flange 19b. However, for operation of the bit, housing 14 is driven to an upper position on mandrel wherein end 14a abuts against shoulder 19a.

Housing 14 is driven upwardly by injection of hydraulic fluid into a chamber 26 formed between the housing and the mandrel. In particular, in chamber 26 a piston face 28 is formed on the housing against which fluid pressure can act to drive the housing along mandrel 12. Piston face 28 is in communication with inner bore 13 of

the mandrel via ports 30, such that fluid pressure applied from surface, such as during pressuring up of the drill string communicated through bore 13 and into chamber 26. Seals 32, 33 act between the housing and the mandrel to contain fluid pressure within the chamber.

To enhance operation of chamber 26 to move housing 14 upwardly over the mandrel, bore 13 has formed or positioned therein a restriction nozzle 34 to increase the pressure in the mandrel inner bore above the nozzle, in ports 30 and in chamber 26. Restriction nozzle 34 acts as to increase the pressure differential between the fluid pressure in these parts and the pressure external to the tool in the borehole in which the bit is operated.

While housing 14 and mandrel 12 can move axially with respect to each other, they are restricted from relative rotational movement by an interlock arrangement such as a splined area 36 on the mandrel that mates with a similarly shaped area 37 on the housing or other arrangement. The interlock arrangement ensures that torque applied to the mandrel is transferred to the housing and thereby to the plurality of bit arms 15 mounted in slots 42 on the housing.

Bit arms 15 include cutters 16, 16b at their lower surfaces and are pivotally connected at their opposite ends by pins 46 to housing 14. The pivotal connection permits arms 15 to move between the stored position within slots 42 and the radially expanded position wherein cutters 16, 16b extend out from slots 42 past the outer surface of the housing. In the radially expanded position, cutters 16, 16b are exposed for enlarging the well bore. The position of each bit arm in the radially expanded position is limited by abutment of surface 50 against upper end 42a of the slot in which it is mounted. In addition, each arm includes a hook 53 on each of its side edges. The hooks are selected to engage under shoulders 54 formed in the slots. Together with abutment of surface 50 against upper end 42a of the slot, the engagement of hooks 53 under shoulders 54 provide thrust support for the arms during use.

Bit arms 15 are mounted to extend through slots 42 into lower inner bore 14f of the housing when it is in the lower position on the mandrel and the mandrel is retracted up into the housing. As such, arms 15 when in the stored position, can abut against

one another at or about the center axis of inner bore 14f. To reduce the effective outer diameter, d, of the arms 15 in the stored position, a portion of 56a of the arm rear surface can be formed, for example as wedges, to fit closely together (Figures 5 and 6).

Bit arms 15, as noted hereinbefore, are driven radially outwardly when the housing is moved upwardly over the mandrel. In particular, the arms are driven outwardly by abutment of end 12a of mandrel against the rear surfaces of the arms.

In the expanded position, the arms are held out by the mandrel. The arms can be supported about their sides and rear surfaces to enhance their durability and strength. In particular, slots 42 are formed at their upper ends 42a and sides 42b to substantially conform to the sides of the arms. In addition, the arms can be formed with respect to the mandrel such that when they are in the expanded position, they are supported adjacent their ends by the mandrel. In particular, the arms have curved rear surfaces 56b which substantially correspond to the outer curvature of the mandrel adjacent its lower end. This close positioning provides that forces can be effectively transferred from the arms to the housing and the mandrel.

The cutter face of the bit is formed by the center cutter face including cutters 18 on mandrel 12 and the outer cutter face formed by cutters 16a on arms 15, when the arms are expanded out and mandrel 12 is positioned between them. The relative sliding movement of the mandrel and the housing is selected such that, the mandrel is positioned with center cutter face substantially co-planar with the outer cutter face when the bit is expanded for use. In the illustrated embodiment, the cutter face also includes cutters 59 positioned on the lower end of the housing to facilitate the formation of a borehole using the bit. Cutters 16b, positioned on the outwardly facing front surfaces of the bit arms are useful for reducing failure due to wear of the arms and clean out the hole behind the cutter face of the bit. While percussive type cutters have been shown, it is to be understood that other cutter types can be used.

Ports 57, in communication with bore 13, are provided, as in a standard bit, to lubricate and clean the cutting face. Ports 57 open in the center cutter face. However, due to the nature of bit operation, fluids jetted through the ports will also pass over, clean and lubricate cutters 16a, 16b and 59. Expansion of the arms is

also facilitated by jetting of fluid though ports 57 during pressuring – up of the drill string.

In operation, it is advantageous that the housing not move over the mandrel every time there is a pressure drop. Thus, in one embodiment, there is provided a releasable lock assembly to lock mandrel 12 and housing 14 in the operating position. In the illustrated embodiment of Figures 1 and 1A, the releasable lock assembly is a spring-biased detent arrangement including a plurality of spring-biased detents 66 in the housing which engage in a groove 68 in the mandrel. The spring force of detents 66 is selected to be greater than the force generated by the weight of housing 14 and arms 15, which would tend to pull the housing down over the mandrel. However, the spring force of the detents 66 can be overcome to move the housing down and allow retraction of bit arms 15 when a selected force is applied, such as the force generated by pulling the arms against the end of the casing to trip the bit to surface. Upper surfaces 15a of the arms are ramped to facilitate folding down of the arms when they are butted against the end of the casing. Detents 66 can be replaced with other lock means, as desired.

To facilitate manufacture, mandrel 12 and housing 14 can be formed in sections as shown and threaded together or secured in some other way. Pins 46 are conveniently installed through bores in the housing and secured between shoulders 70 and bolts 72. Detents 66 are installed in ports 74 by threaded caps 76.

Referring to Figures 7 to 12, there is shown another expandable bit according to the present invention. The bit includes a mandrel 112, a housing 114 and a pair of bit arms 115 supported on the housing. Mandrel 112 includes a lower end 112a and an inner bore 13 with a venturi nozzle 34 formed therein.

Housing 114 includes a lower end 114b and an inner bore 114c in which mandrel 112 is telescopically disposed. A hydraulic chamber 26 is formed between the housing and the mandrel and includes a piston face 28 formed on housing 114. The hydraulic chamber reacts to fluid injection though bore 13 to drive the housing axially over the mandrel.

An interlock arrangement 36, 37 is provided between the mandrel and the housing to prevent relative rotational movement therebetween. The under reamer includes a

releasable operational lock assembly including a plurality of spring-biased detents 66 and a groove 68.

Bit arms 115 have mounted thereon cutters 116. The bit arms 115 are pivotally mounted by pins 146 in slots 142 in a region of the housing from which mandrel 112 is retracted when the housing is in the lower position on the mandrel. In this position, arms 115 extend into bore 114c when the mandrel is retracted, but are pushed out into an expanded position by the center cutter face 118a of the mandrel when the housing is driven axially up over the mandrel by injection of fluid into chamber 26.

In the illustrated embodiment, slots 142, and thereby arms 115, are spaced from end 114b of the housing such that arms 115 are spaced from the center cutter face 118a on the mandrel when the bit is expanded for use. However, cutters 159 are disposed on the housing between end 114b and the slots 142 such that a substantially continuous cutter face is provided including cutters 116 on the bit arms, cutters 159 on the housing and the center cutter face 118a. This cutter face provides extended cutter engagement with the borehole wall during formation of a borehole.

By use of only two bit arms 115, the arms can be elongated and positioned to overlap in bore 114c in side-by-side configuration when in the stored position. Slots 142 are formed to closely surround the bit arms to support them in the expanded position. Each bit arm includes a shoulder 153 which engages under a shoulder 154 formed in the slot. In addition, the lower end of each bit arm is selected to engage under the lower end of its slot when in the expanded position. This limits outward expansion and stabilizes the arms by being secured both at their top and bottom ends.

Ports 157 extend from bore 13 and open into center cutter face 118a. Channels 180 are formed in the center cutter face and channels 182, which substantially align with channels 180 when the cutter face 118a is exposed for use at the end of the housing, are provided to facilitate flow of fluid, as shown by the arrows in Figure 10, from ports 157 along the cutter face to the clean and lubricate cutters 116 on the arms.

Referring to Figures 13 and 14, there is shown another expandable bit according to the present invention. The bit is generally similar to the bit of Figure 1 and includes a mandrel 212, a housing 214 and bit arms 215 supported on the housing. However, the mandrel and the housing are formed such that in the expanded position, mandrel 212 is distanced out from the lower end 214b of the housing. As such, the cutter faces, formed by cutters 216, on the bit arms are spaced from the center cutter face 218a on the mandrel during operation of the bit to drill a borehole.

Ports 257 open into center cutter face 218a and are positioned in channels 280 formed in the center cutter face. Channels 280 which substantially align with channels 282 on the bit arms, when the bit is in the expanded position, to facilitate flow of fluid from ports 257 along the cutter face to the clean and lubricate cutters 216 on the arms.

Although various embodiments of the present invention have been described in some detail hereinabove, those skilled in the art will recognise that various substitutions and modifications may be made to the invention without departing from the scope and spirit of the appended claims.